ASJ: *International Journal of Health, Safety and Environment (IJHSE)*
Vol. 6 (07) 30 August, 2020, Pp. 627 – 637
www.academiascholarlyjournal.org/ijhse/index_ijhse.htm
ISSN: 2360-9311©Academia Scholarly Journals
Indexed In: Directory of Research Journals Indexing - http://www.drji.org
Also Available@: Archive.org/Nwaerema_et_al.
Open access

Full Length Research

Characterization of Air Quality Index (AQI) of Port Harcourt Tropical Littoral City, Nigeria

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Accepted August 28, 2020

The present investigation was carried out on the characterization of Air Quality Index (AQI) of Port Harcourt Tropical Littoral City in Nigeria. This study used Testo 350XL Gas Analyzer (NO_x and CO) and 5 in 1 multi-function laser sensor BRV8 (PM_{10} and $PM_{2.5.}$ detectors) for air quality measurements. The field data were converted into AQI values. The Geographic Positioning System (GPS) was used to establish the sample locations. Findings showed that Carbon Oxide (CO) at 32.7% contributed the greatest threat to life and $PM_{2.5}$ (15%) had the least harmful effect. In a population of 3,235,840 only 8.8% persons had good and satisfactory AQI. The unhealthy and unsatisfactory category of 2,951,655 people accounted for 91.2% in the AQI classification with expected respiratory symptoms. The very unhealthy AQI classification was found in areas of Aba Express Road, Mile One, Rumuola, Artillery, Garrison and Woji respectively. The good and satisfactory AQI category was located at the fringes of the Air Port. The result showed that AQI in the morning differed significantly from that of the evening. Therefore, the people and authorities should mitigate environmental pollution in Port Harcourt City of Nigeria.

Keywords: Air Quality Index (AQI), Environment, Health, Pollution.

INTRODUCTION

Globally, air pollution is one of the greatest environmental health challenges. Per annum air pollution has caused about 6.5 million early death and 92% of the world population breathe polluted air incessantly (WHO, 2016). It is estimated that 1 out of 10 children die of contaminated air and 90% of the children breathe polluted air as well as 9 out of 10 people breathe highly contaminated air globally (WHO, 2018). The world spends $5 trillion as cost of welfare issues on early or premature death and 225 billion in lost labor due to poor air quality (World Bank, 2016). The problem of breathing toxic air has resulted to the concept of AQI. The AQI is a standardized technical instrument and summary measures used to

assess the extent or degree of health risk in ambient air as contributed by particulate and gaseous air pollution. It determines the health effects to be experienced on hourly and daily basis. Such pollutants could be nitrogen dioxide, ground-level ozone, particulate matter, sulfur dioxide and carbon monoxide, AQI is used to establish air quality standards to protect public health (NOAA, 2020). Primary air pollutants produced by human activities include Sulphur Oxides (SO_x), Nitrogen Oxides (NO_x), Carbon Oxide (CO), Volatile Organic Compounds (VOC), Particulate Matter (PM), Persistent free radicals, Toxic metals such as lead and mercury, Chlorofluorocarbons (CFCs), Ammonia (NH_3), odors from garbage, sewage and industrial processes and radioactive pollutants produced by nuclear explosions. The secondary air pollutants include articulates created from gaseous primary pollutants and compounds in photochemical smog, ground level ozone (O_3) produced from NO_x and VOC_s (Mahendra and Vaibhav, 2013; WHO, 2017). However, it has been known that air pollution has caused severe damages to the human body such as breathing difficulty, cardiac malfunctioning, sneezing and coughing, wheezing and general respiratory problems as well as eventual death. The damage caused by air pollution is directed to the human cardiovascular and respiratory systems which could destabilize the overall wellbeing of the people. Thus, people react to air pollution differently, depending on the extent of concentration and exposure as well as genetic composition. Toxins in the air could react with one another to form acid rain and ground level ozone. The product of such reaction could destroy both plants and animal species including trees, farm crops and livestock. Toxins in the air on reaching the ground will pollute water bodies which humans, plants and animals depend on for survival. Therefore, air pollution has the capacity to destroy the economy of a place and cause loss of valuable resources yielding billions of monies annually. Damages caused by air pollution could make people's productive energy to drop due to associated ailments (Gary et al., 2009; Ghorani‐Azam et al., Loomis et al., 2014; Mahendra and Vaibhav, 2013; Mellouki et al., 2016; World Bank, 2016). From the preceding literature, it has become obvious that several cities are affected by poor air quality. Thus, the AQI of most Nigeria cities has not been carried out, resulting to limited literature and gaps in air quality study, of the country. So, this research was aware about the gap in the study of air pollution of cities, thereby, leading to this investigation. Therefore, the objective of this research is to understand the AQI characteristics as it affects the health of people in Port Harcourt Littoral City, Nigeria.

MATERIALS AND METHODS

This study covers the Littoral City of Port Harcourt in Rivers State situated within longitude $7^{0'}$E and $7^{0'}$5 E and latitude 4^{0}45'N and 4^{0}50'N in the Tropical country of Nigeria; surrounded by Okirika, Eleme, Etche, Ikwere and Emohua Local Government Areas (Figures 1 and 2).

Data for this research were drawn from elaborate data of Edokpa et al., (2019). The data were generated from the field in the month of January across 10 sample locations in Port Harcourt. A handheld digital air quality measuring device of Testo 350XL Gas Analyzer (NOx, and CO) and 5 in 1 multi-function laser sensor BRV8 (PM10 and PM2.5. detectors) were used to capture the pollutants at ground level at 0006-0009 (morning) and 00017-00020 (evening). The Geographic Positioning System (GPS) was used to establish the study area location coordinates. The locations were selected due to the pollution concentration resulting from vehicular traffic, industrial activity and density of other anthropogenic activities. The raw data were transformed to the air quality heat index condition using the formula:

$$IP = \frac{IHi-ILo}{BPHi-BPLo}\text{(Cp-BPLo) + ILo} \quad \text{--------------------(1)}$$

Where IP = the index for pollutant P
CP = the rounded concentration of pollutant P
BPHi = the breakpoint that is greater than or equal to CP
BPLo = the breakpoint that is less than or equal to CP
IHi = the AQI value corresponding to BPHi
ILo = the AQI value corresponding to BPLo

Finally, the Student (t-Test) statistics at 0.05% significance was use to establish the statistically significance difference between AQI in the morning and in the evening.

RESULTS

The spatiotemporal distribution of Port Harcourt City area during the study period was according to Table 1. The very unhealthy AQI (201-300 purple) was

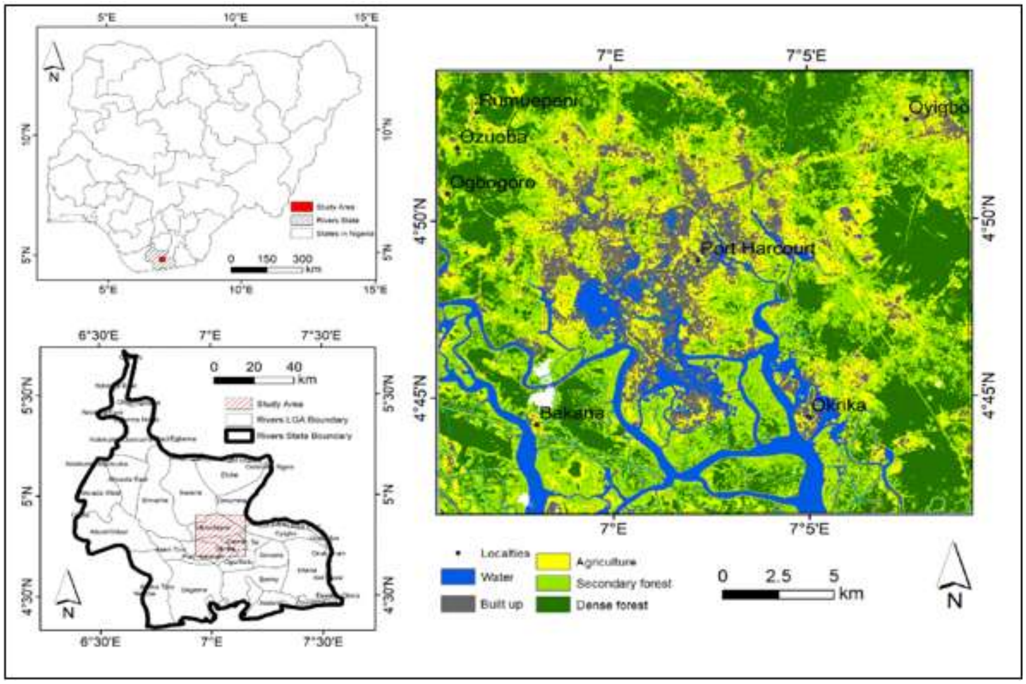

Figure 1. Port Harcourt City Area.

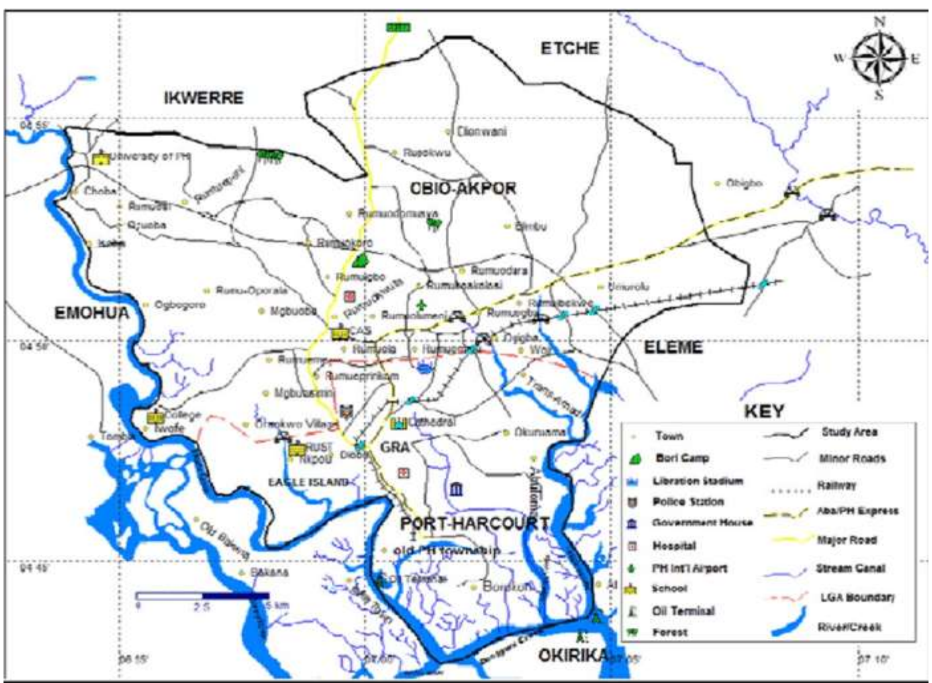

Figure 2. Map of Port Harcourt City Layout and Routes
Source: Adapted from Akukwe and Ogbodo (2015).

common in the areas of Aba Express Road, Mile One, Rumuola and Artillery. The implication was that people at risk within these areas would be those with respiratory or heart disease, the elderly and children

Table 1. Area Air Quality Index (AQI).

		AQI							
Location	**Geocodes**	**NOx (µg/m³)**		**CO (µg/m³)**		**$PM_{2.5}$ (µg/m³)**		**PM_{10} (µg/m³)**	
Time		**0006-0009**	**17000-20000**	**0006-0009**	**17000-20000**	**0006-0009**	**17000-20000**	**0006-0009**	**17000-20000**
Aba Express Road	4o47I 58.24IIN/ 7o00I 22.11IIE	111	123	238	150	56	78	102	102
Trans-Amadi	4o48I 43.30IIN 7o01I 08.28IIE	113	106	112	77	61	63	94	87
Mile One	4o49I 24.22IIN 6o59I 36.12IIE	121	136	195	210	65	67	107	111
Garrison Junction	4o48I 43.30IIN 7o00I 30.35IIE	131	125	138	180	84	72	121	78
Rumuola Junction	4o50I 00.33IIN 7o00I 23.45IIE	136	142	225	202	80	69	133	152
Artillery Junction	4o50I 37.07IIN 7o02I 18.96IIE	152	155	86	232	69	67	128	142
Rumuokoro	4o52I 00.68IIN 6o59I 58.56IIE	136	133	143	131	82	91	111	126
Waterlines Junction	4o49I 02.18IIN 7o00I 32.67IIE	134	117	108	142	74	71	113	108
Port Harcourt Airport	5o00I 25.45IIN 6o57I 02.36IIE	46	46	12	11	61	13	14	16
Woji	4o49I 42.52IIN 7o03I 28.67IIE	113	108	169	87	59	47	78	90
Mean		125	123	146	141	66	66	102	222
Mean Total		125		144		66		105	

would suffer heart and lung diseases as well as premature mortality of people with combined cardiopulmonary disease. The general population at this level would be at risk of respiratory effects (Tables 2 and 3). Therefore, people with respiratory or heart disease, the elderly and children should avoid any outdoor activity and prolonged exertion.

The unhealthy AQI (151-200 red) was observed within Aba Express Road, Mile One, Garrison, Rumuola, Artillery and Woji areas respectively. The recorded AQI showed that these areas had serious health risk of people with respiratory disease with likely respiratory symptoms accelerated by lung disease such as asthma. The cautionary measure

Table 2. Categories of AQI and their meaning.

Air Quality Index (AQI) Values	Levels of Health Concern	Colors	Meaning
When the AQI is in this range:	...air quality conditions are:	...as symbolized by this color:	
0-50	Good	Green	Air quality is considered satisfactory and air pollution poses little or no risk.
51-100	Moderate	Yellow	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
101-150	Unhealthy for Sensitive Groups	Orange	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
151-200	Unhealthy	Red	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
201-300	Very Unhealthy	Purple	Health warnings of emergency condtions. The entire population is more likely to be affected.
301-500	Hazardous	Maroon	Health alert: everyone may experience more serious health effects.

was for the people with respiratory disease such as asthma to limit outdoor exertion. The unhealthy for sensitive group AQI (101-150 orange) was dominant within the Trans-Amadi, Rumuokoro and Waterlines areas. AQI at these areas showed that people with respiratory disease were at risk and would likely have respiratory symptoms aggravated by lung disease such as asthma. Thus, people with respiratory disease should limit outdoor exertion (Tables 1 to 3).

The effects of the various categories of AQI on the population are displayed in Figure 3. The unhealthy sensitive category AQI (101 – 150) had 1, 414, 470 people affected. It showed the highest category of people with respiratory disease at risk and would likely have respiratory symptoms aggravated by lung disease such as asthma. The implication was that 43.7% of the population were members of sensitive group suffering respiratory ailments affected by the

Table 3. AQI, Sensitive Groups, Health Effects and Cautionary Statements.

AQI (AQI) Value	Sensitive Groups/ Health Effects Statements/ Cautionary Statements
0-50	**Sensitive Groups: a**ir pollution is considered satisfactory and poses little or no risk to people. **Health Effects Statements: e**xtremely reduced respiratory and lung diseases such as asthma; possibly no respiratory effects in the general population. **Cautionary Statements: p**eople with respiratory or heart disease, the elderly and children should consider any outdoor activity with little or no risk and good exertion.
51-100	**Sensitive Groups:** people with respiratory disease are the group most at risk. **Health Effects Statements:** reduced respiratory symptoms and lung disease such as asthma; little or no respiratory effects in general population. **Cautionary Statements:** people with respiratory or heart disease, the elderly and children should consider any outdoor activity with little or no risk and good exertion. The general population has little of no risk.
101-150	**Sensitive Groups:** People with respiratory disease are the group most at risk. **Health Effects Statements:** increasing likelihood of respiratory symptoms and aggravation of lung disease, such as asthma. **Cautionary Statements:** people with respiratory disease, such as asthma, should limit outdoor exertion
151-200	**Sensitive Groups:** people with respiratory disease are the group most at risk. **Health Effects Statements:** increased respiratory symptoms and aggravation of lung disease, such as asthma; possible respiratory effects in general population. **Cautionary Statements:** people with respiratory or heart disease, the elderly and children should avoid any outdoor activity; everyone else should avoid prolonged exertion.
201-300	**Sensitive Groups:** people with respiratory or heart disease, the elderly and children are the groups most at risk. **Health Effects Statements:** significant aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; significant increase in respiratory effects in general population. **Cautionary Statements:** people with respiratory or heart disease, the elderly and children should avoid any outdoor activity; everyone else should avoid prolonged exertion.
301-500	**Sensitive Groups:** Everyone should avoid outdoor exertion. People with respiratory or heart disease, the elderly and children are the groups most at risk. **Health Effects Statements: s**ignificant aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; significant increase in respiratory effects in general population. **Cautionary Statements: -** people with respiratory or heart disease, the elderly and children should avoid any outdoor activity; everyone else should avoid prolonged exertions. Everyone should try to stay indoors. Limit physical activity. Shut windows and doors if it is not too hot. Set home air conditioners on the recirculation mode if this is available. If it is too hot to shut windows and door, consider leaving the area until the air quality improves. Operators of larger, nonresidential buildings should check with health professionals to determine the best course of action.

poor air quality of Port Harcourt City. The healthy and very unhealthy groups accounted for 284, 185 and 203, 451 of people affected by the AQI. It showed that 8.8% of members of the public and very sensitive people experienced more serious health problems and 6.3% were extremely severe while the entire

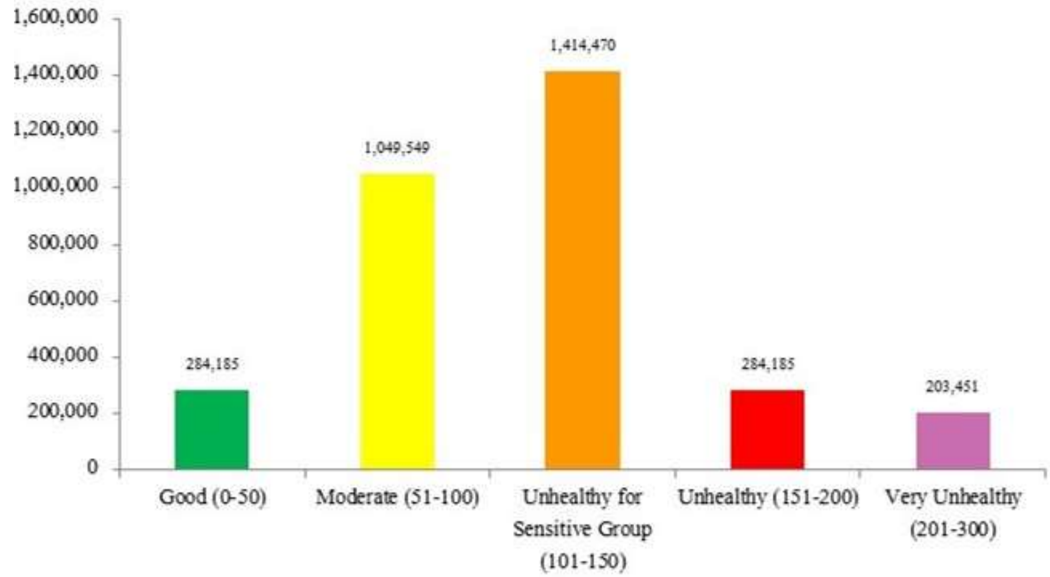

Figure 3. Effects of AQI on Population.

population was more likely to be affected by the poor air quality especially older people and children with respiratory disease such as asthma. However, the moderate and good groups accounted for 1,049,549 and 284,185 people respectively. It showed that 32.4% of the people had moderate air quality and health concern while 8.8% had air quality considered satisfactory. It displayed that in Port Harcourt City, 284,185 (8.8%) people enjoyed good and satisfactory air quality free from harmful concentration of air pollutants.

However, among the air pollutants investigated, CO accounted the greatest threat to human lives in the City with 32.7% contribution to poor AQI. Thus, NO_x contributed 28.4% recording the second highest air pollutant harmful to the Port Harcourt City dwellers. The PM_{10} and $PM_{2.5}$ contributed 23.9% and 15% harmful effects to the people with the PM_{10} ranking the third and $PM_{2.5}$ the least contributor. These and many other sources contribute to the unhealthy air quality of Port Harcourt City. Resultantly, CO having the highest contribution to air pollution quality was because of the high volume of vehicles, increased power generator sets, illegal crude oil refining, bush burning, waste burning and other carbon emission sources very common in the City and its fringes (Figure 4).

The evening period of the day recorded the unhealthiest period in Port Harcourt City (Figure 5). The good category (0-50) though satisfactory index recorded higher number of people with health issues in the evening than in the morning. Moderate group (51-100) which was the acceptable index recorded equal unhealthy people in the morning and evening. The unhealthy sensitive group (101-150) harmful to people with respiratory disease showed more harm in the morning than in the evening. The unhealthy index (151-200) showed that everyone may begin to show health effects in the evening than in the morning. Finally, the very unhealthy (201-300) indicated that everyone may begin to show health effects in the evening than in the morning. There was no record of hazardous (301-500) AQI in Port Harcourt City which usually cause health alert by everyone experiencing more serious health effects. The AQI between morning and evening has the calculated t-value of 0.108712963 and critical t-value of 1.990847069 with 78 degrees of freedom for a two-tailed test at 0.05 significant levels. It denotes that calculated value (0.108712963) is lower than the critical f-value of 1.990847069. It therefore shows that AQI in the morning differ statistically significant from that of the evening. This is in tandem with the previous view that the evening period recorded the unhealthiest period in Port Harcourt City in the heat index categories of good (0-50), moderate (51-100) and unhealthy (151-200) respectively except unhealthy sensitive (101-150) category which

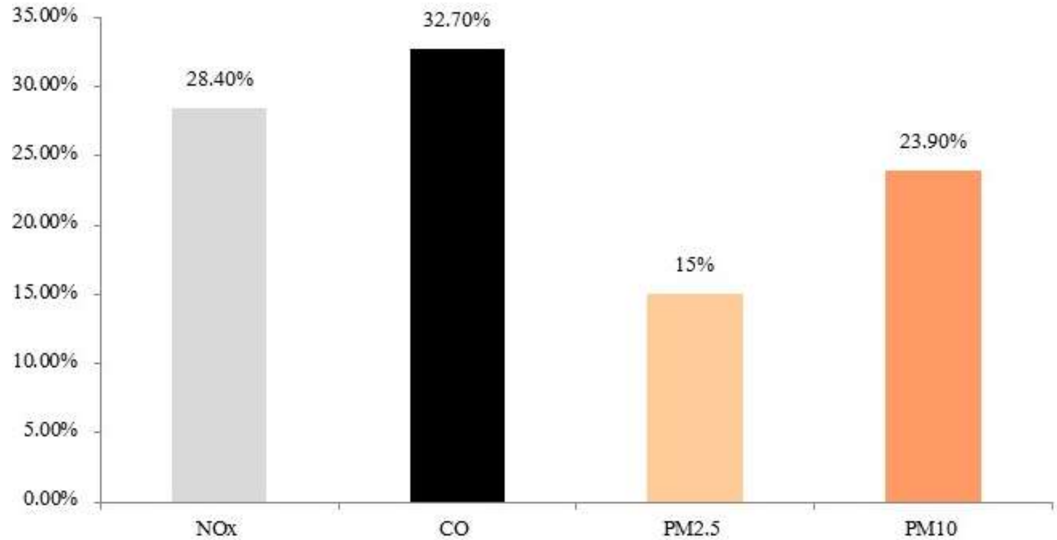

Figure 4. Levels of Pollutants Contribution to AQI.

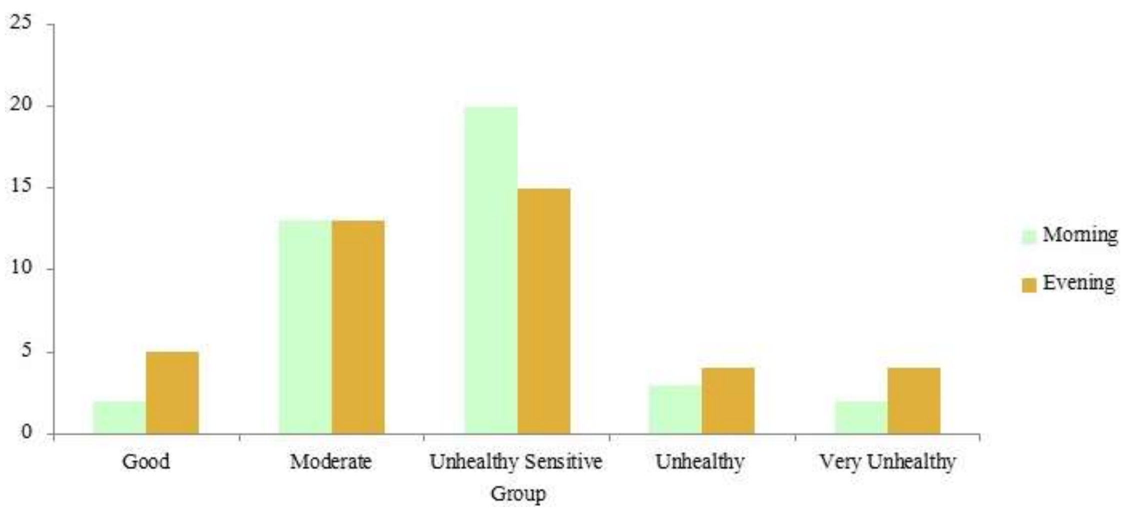

Figure 5. Effects of AQI in the Morning and Evening.

showed more harm in morning than in the evening.

DISCUSSION

The moderate AQI area (51-100 yellow) was found dominantly in Trans-Amadi, Woji and artillery inclusively. In this category, people with respiratory disease were the group most at risk but there was expected reduction in respiratory symptoms and lung disease such as asthma and little or no respiratory effects in the general population. People with respiratory or heart disease in these areas such as the elderly and children should consider any outdoor activity with little or no risk and good exertion. The good AQI (0-50 green) was common in the Air Port area and a little notice within Woji area. In this category air pollution is considered satisfactory and poses little or no risk. Thus, there was reduced respiratory and lung diseases such as asthma, extremely little or no respiratory effects in general population. However, people with respiratory or heart

disease, the elderly and children should consider any outdoor activity with little or no risk and good exertion. This category has satisfactory AQI which is usually experienced at the rural fringes as in the case of Air Port area which is located at the outskirts of Port Harcourt City. This is because the green plants help in purifying the air. According to Federico et al. (2018), plants have the phytoremediation capacity to improve air quality and energy consumption in the City environment. Also, there is usually limited vehicular movement and low economic activities at the rural fringes thereby resulting to low pollution and health risk. Thus, the AQI of Port Harcourt City ranged between 11 and 238 (227 difference) of low and high impact areas. This showed that the City's air quality was very unhealthy, capable of causing severe respiratory damage to people at all levels of life.

The unhealthy sensitive category AQI (101 – 150) affected 1, 414, 470 people in the city with elderly and children mostly affected. This study is similar to the investigation of Małgorzata et al., (2017) who carried out study of the air quality index of PM_{10} and Sulphur dioxide concentrations and its effects on the population of Katowice area. The results of the study showed that between 2001 to 2002, unhealthy AQI was between 0.1% and 11.2% index levels during winter season. The relationship between air quality index and total deaths showed that people at 65 years and above suffered more death resulting from cardiovascular and respiratory diseases.

Furthermore, this study showed that PM_{10} had more concentration than $PM_{2.5.}$ In contrast, Osimobi et al., (2019) studied the daily AQI of PM_{10} and $PM_{2.5}$ in the University of Port Harcourt campus. The study showed that PM_{10} concentration was less than $PM_{2.5}$ in the air of the University campus with $PM_{2.5}$ having 52.68% of the total concentration. This contrast could be as a result of relatively limited vehicular movement on campus and more $PM_{2.5}$ generating sources on the campus, facilitated by the location of the campus at the outskirts of the city occupied with more plants and campus greening. Also, Gowtham and Anjali (2015), investigated AQI of $PM_{10,}$ $PM_{2.5}$, SO_2 and NO_2 of Vapi City. The findings showed that SO_2 and NO_2 were on the good and satisfactory categories, while PM_{10} and $PM_{2.5}$ were on the satisfactory and moderate categories, which PM_{10} was known as the highest pollutant in the AQI of the city similar to this study.

Carbon Monoxide accounted for the most toxic pollutant in a city especially from motor vehicles. This is in the same view with the observation of Cartaxo (2018) which motor vehicles of different types contribute 75% of carbon monoxide emissions. Moreover, illegal oil refining and oil theft in Nigeria (Port Harcourt City inclusively) accounts for 400,000 barrels of oil loss per day (US$1.7-billion) thereby contributing to the overall emission of hydrocarbon toxins to the City air (Dalby, 2014; Boris and Job, 2015).

The severity of poor health in the evening of Port Harcourt is due to the release and concentration of more air pollutants during work hours and the likelihood of rush hour vehicular traffic and domestic use of power generating set in the evening. This finding is the same view with that of Francis et al. (2015), which showed that air pollutants vary in space and time of day in Imo State of Nigeria.

CONCLUSION

Characterization of AQI of Port Harcourt Tropical Littoral City has become very pertinent due to the incessant air pollution taking place in the City. Resultantly, humans, animals and plant species are at serious risk of the imminent disaster. Thus, intensive air quality field measurement and converting the air quality values into heat index conditions have been useful in the study. The very unhealthy and unhealthy AQI are common in the areas of Aba Express Road, Mile One, Rumuola and Artillery, Garrison and Woji areas respectively indicating that those with respiratory or heart disease, the elderly and children as well as people with combined cardiopulmonary disease are more at risk. The good AQI is noticeable in the Air Port area indicating that it has satisfactory air quality condition promoted by the vast land of green vegetation causing air sinking and purification. Among the investigated air pollutants, CO has accounted the greatest threat to life in the City with 32.7% contribution to the AQI; due to the high influx of vehicles, increased power generator sets, illegal crude oil refining, bush burning, waste burning and other carbon emission sources. However, $PM_{2.5}$ is the least air quality pollutant contributing 15% harmful effects to the City dwellers. The evening period in Port Harcourt City has high rate of air pollution effect than the morning period. The result shows that AQI in the morning differ significantly from that of the

evening. Thus, in a population of 3,235,840, the unhealthy sensitive category of 1,414,479 people accounts for 43.7% of the AQI group showing people with respiratory disease at risk and would likely have respiratory symptoms aggravated by lung disease such as asthma; and 284,185 (8.8%) people enjoy good and satisfactory air quality condition in the City. Therefore, the continuous release of pollutants in the air of Port Harcourt will keep lowering the environmental air quality and health conditions of the City dwellers. Thus, air, land and water as well as animal and plant species are at great risk of surviving the disaster caused by poor air quality condition of the Port Harcourt City. It is recommended, therefore, for the government, policy makers and general public to rise up against this deadly air hazards by proper planning, management and execution of appropriate AQI framework by monitoring and evaluating sources of air pollution in the City as well as practice urban greening for inhabitable Port Harcourt City of Rivers State, Nigeria.

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